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**Sonar Dome Reliability XVIII: Measured
Deflections of the USS Kauffman Sonar
Rubber Dome, 15-25 Nov 1992**

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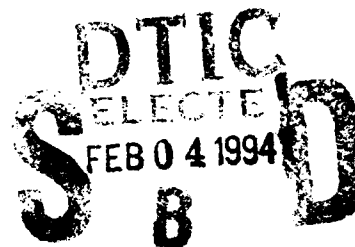
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13. ABSTRACT (Maximum 200 words) Deflection measurements were performed on the Sonar Rubber Dome (SRD) of the USS Kauffman using an acoustic time-in-flight system. This report documents modifications of the previous deflection measurement system, field tests of the experimental equipment, the installation process, initial shakedown cruise, and describes the data collected during the at-sea voyage of 15-25 Nov 1992. We obtained comprehensive deflection data on 65 locations of the SRD as well as extensive environmental data. The environmental data included ship speed and course, dome pressure and temperature, roll, pitch, sound speed and salinity inside the SRD, and 3D acceleration. The deflection measurement system suffered a performance degradation after installation, and possible causes are discussed.					
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**SONAR DOME RELIABILITY XVIII:
MEASURED DEFLECTIONS OF THE USS KAUFFMAN
SONAR RUBBER DOME, 15-25 NOV. 1992.**

INTRODUCTION

This report contains a description of Sonar Rubber Dome (SRD) deflection measurements made on the USS Kauffman, culminating in the Antigua sea trial of 15-25 Nov. 1992. Included is a description of the full data set collected, the grooming and initial transformation to Cartesian coordinates, and consideration of some of the problems encountered as relevant to the interpretation and post-analysis of this data set. It is emphasized that this report only constitutes a first communication of this groomed data set; additional analysis and interpretation will appear in subsequent reports.

Sonar Rubber Domes (SRD's) and Sonar Dome Rubber Windows (SDRW's) are large rubber-wire composite structures used on US Navy surface ships to protect the ship's sonar array by providing an outer hydrodynamic flow contour. In addition, the domes are also designed to be acoustically transparent in the operating frequency range of the sonar systems. This allows for maximum energy transmission and reception between the ship's sonar and the ocean. Figure 1 shows both types of domes on Navy ships in drydock.

Dome failure negates the above properties and requires a ship to break deployment and return to drydock at minimal speed to prevent damage to the sonar array. NAVSEA, Code 91W4D, has an ongoing effort to determine the cause(s), and prevent future occurrences, of dome failures. A critical part of this effort is the at-sea measurement of dome structural response to ship motions, internal pressurization changes, and sea state, under operational conditions. This data can then be used to validate finite element modeling, necessary for assessing the probable effectiveness of future design changes for failure prevention. The original sea test plan that we sent through NAVSEA to the Navy is included as Enclosure 1.

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The measurement system is based on acoustic time-of-flight and sound speed measurements which, in combination, allow for calculation of 3D transducer locations. An array of hydrophones, used as acoustic driver transducers, are attached to the inner surface of the dome in a pattern which gives the most useful information on deflections in regions of interest. These transducers are sequentially excited, and their acoustic signals are collected by receiver hydrophone arrays placed to guarantee a direct acoustic sound path. Knowledge of the timing of the excitation and receiver pulses, the sound speed, and the relevant geometry, allows conversion of the time-of-flight measurements to three dimensional coordinate information.

Figure 2 shows a computer model of an SRD with the ship's sonar array, baffle plate, adapter plate, and the various subsystems for deflection measurement, i.e. the two junction boxes each with four star modules. The red stars show the planned locations of the 128 hydrophones. This model was used to estimate the best locations for the receiver arrays.

Concurrently with the deflection measurements, environmental data, such as ship's course and speed, sea state, and internal dome pressure, are collected and related to hydrophone position at corresponding times. Thus the motions of various parts of the dome can be correlated to the external forces on the dome. A full description of the measurement system used in recording dome deflections, ship motions, and ship environmental data has been previously presented^[1]. An earlier version of the deflection measurement system, designed particularly for SDRW's, was used aboard the USS Yorktown^[2]. The present version of the system has been modified for use on SRD's^[1]. The USS Kauffman (FFG 59) was selected by the Navy as the test ship for the most recent SRD version of the at-sea deflection measurement portion of this corrective action program.

FIELD TEST AT CHESAPEAKE BAY DETACHMENT OF NRL

From August 1991 to January 1992 a prototype SRD Deflection Measurement (SRDDM) system was installed on an old SRD at the Chesapeake Bay Detachment (CBD) of NRL. This dome was mounted in a shipping fixture, sandbagged underneath for additional support, and water filled to allow for acoustic tests on hydrophone placement, directivity, and overall system checkout. The top two pictures in Figure 3 show the dome used at CBD with the test system installed. The electronic and computer equipment was housed in a portable trailer shown in the background.

Our work at CBD began with the implementation of the B.F. Goodrich (BFG), Jacksonville, FL, procedure for establishing a grid system on the inner surface of the SRD. This grid system procedure, necessary for the accurate location of the hydrophones, was first tested at CBD. Minor modifications were made including the substitution of a laser leveler for the suggested plumb bob. This modified system was used subsequently at BFG as described in the following section. We then installed and tested the deflection measurement system.

This testing was instrumental in identifying needed system improvements, and for use in designing, testing and implementing modifications.

First, and most crucial, the testing at CBD revealed the necessity for independent computer controlled amplifiers for each receiver channel in order to equalize received signals before interfacing with the timer threshold levels. These are required to provide for consistent time of flight readings despite wide variance in separation distance and directivity angles. This had not been needed in the previous SDRW system due to the uniform spacing and geometry of the hydrophone - receiver combinations. The CBD test platform allowed us to test prototype amplifier designs as well as the final versions used subsequently at sea.

Several planned hydrophone locations were relocated to allow for direct, line-of-sight, acoustic reception. The SRD used at CBD was equipped with aluminum sheet metal mockups of an SQS-56 sonar array and a WQC-2 intership communication transducer that allowed us to test for acoustic multiple path problems. These mockups also enabled us to perform experimental validations and minor adjustments of the computer selected positions for all 10 receiver arrays.

All of the electrical cabling and connections for the hydrophones, receiver arrays, star modules, and junction boxes, as well as the main system cabling were tested under near operational conditions. Realistic testing was done on trigger level signal processing hardware, and improvements were added that provided more accurate threshold levels for consistent timer activation. The final version of this signal processing hardware consisted of two stages of analog squaring followed by high and low pass filters as described in Reference [1].

Finally, the CBD test facility supplied the platform upon which all of the software subroutines, used in the Antigua sea trial, were tested under operational conditions similar to those at sea. These routines included several diagnostic system hardware checks, deflection and environmental data acquisition, and various data display and statistical analysis routines.

INSTALLATION

Dome Preparation and Hydrophone Attachment

A new Sonar Rubber Dome, S/N 119 manufactured at BFG, was designated as the experimental dome for use during the deflection measurement sea trial. In May of 1992, we installed 128 hydrophone drivers onto the inner surface of the dome, attaching them with Elastok AS-1 rubber adhesive supplied by BFG. The cables of all the hydrophones were also attached in several places using rubber tabs and AS-1, and were bundled and arranged in preparation for attachment to the ship. The lower two pictures of Figure 3 show the SRD with the hydrophones attached. This dome was then set aside and stored for the drydock installation on the ship to be selected for the sea trial.

The hydrophone attachment procedure required 3 man-weeks and consisted of the following stages: grid layout; marking the 128 hydrophone locations; attachment of the hydrophones; arranging and attaching cable pathways; and bundling the hydrophone cables for storage, transportation, and ease in drydock installation. The grid layout was based on coordinate data supplied by BFG. The coordinate points were connected to form ship frame lines and waterlines as shown in Figures 4 and 5. A laser leveler was used as a guide in drawing the grid lines upon the curved inner surface of the SRD. The grid lines were then used to locate and mark the desired mounting locations for the 128 hydrophones. The Elastolok AS-1 was used in attaching the hydrophones and cables, but the cables also required an additional rubber tab every 30 to 50 cm. The hydrophones were mounted in the positions shown in Figures 4 and 5. This procedure took 3 days to complete due to the difficulties in using the Elastolok, cleaning and positioning the hydrophones, cables, and surface areas of attachment on the SRD, the recording of hydrophone numbers and positions, and arranging the extra cable lengths for subsequent attachment to the ship. In this process only one hydrophone (position 74) was damaged as the density of hydrophones and cables on the SRD surface became quite high. This hydrophone was later replaced by a spare hydrophone during the drydock installation of the SRD onto the USS Kauffman.

Shipyard Installation

Unlike the SDRW deflection measurement system, the SRD version required drydock ship modifications to accommodate the sensors, cables, and computer equipment. The USS Kauffman was scheduled for drydock repairs in late August through October of 1992, and funding was sent to Supship Portland, ME to accomplish the necessary ship modifications. These requested drydock modifications are detailed in Enclosures 1 and 2 and described briefly below.

During previous trips to ships in drydock we had determined that there was insufficient room left in the existing cableways for the addition of our system control cables. Thus, we requested a new cableway be installed between the SRD area and the sonar equipment room, shown in Figures 6 and 7, to provide a pathway for these new cables. The new cableway would also have provided electrical shielding from the ships sonar array cables.

In order to install the wave height sensors in a protected enclosure parallel to the water surface on either side of the bowrails, we had designed a support structure that was to be welded to the outer ship hull. NRL provided the shipyard with precut materials for these two enclosures.

We requested that the drydock ship schedule be modified to allow time for the installation of the system equipment in the SRD area prior to attachment to the ship, and to modify the dome mounting sequence to minimize possible damage to the SRDDM equipment.

We also requested the installation of stuffing tubes for all the various connecting cables, and for the modification of the CPO storage space to allow room for the SRDDM equipment racks. These racks also needed to be installed in a seaworthy manner to withstand high sea state stresses.

However, several of these tasks were not performed as requested, resulting in serious degradation of data collection capabilities. It was jointly decided that a new separate cableway was not needed; the installation of the wave height sensors was made parallel with the ships rail instead of the water surface (3 degrees off); and the drydock schedule did not allow us adequate time to perform the installation of equipment inside the SRD. Additionally, several accidents due to poor coordination at the shipyard resulted in significant impediments to the installation process. Most damaging was the contamination of our computers, hard disc drives, magneto-optical drives, and related equipment with sand blasting material. This apparently did no lasting damage, but required several days to cleanup and further shortened and delayed the installation of our system.

AT-SEA DATA COLLECTION

Shakedown Cruise

The SRDDM system installed on the USS Kauffman did work extremely well during the initial shakedown cruise on October 22, 1992, off the coast of Maine. However, due to a planned emphasis on avoiding directivity problems with the hydrophones (as was experienced on the USS Yorktown) and excessive time spent solving minor problems, the collection of ship environmental data was not implemented during this initial sea test. Thus, even though a large amount of archival quality information on dome deflections was collected, the usefulness of this data was seriously impaired due to the inability to correlate it with ship motions, sea state, etc. The directivity problem was successfully solved and no problems of this nature occurred later in the full sea test. In retrospect, obtaining the environmental data on this shakedown cruise would have been of greater significance.

Thirty data runs were performed during the shakedown cruise, with 20 data runs involving 125 of the hydrophones, and the other 10 runs using various small groups of hydrophones. Several pierside calibration runs were performed, both before and after the shakedown cruise.

We noted during the cruise that more amplification was required on all hydrophone channels than had been necessary pierside in order to obtain functioning data sets. Also, the amount of amplification needed had to be increased several times in some cases to maintain proper functioning. However, this was not deemed as being a major problem at the time since these modifications remained within normal operating ranges.

Antigua Sea Trial

Preparation for the Sea Trial

Between Oct. 22 and Nov. 1 the USS Kauffman reloaded weapons and performed training at sea. No personnel from NRL were aboard. Ships crew reported nothing unusual during this period. However, in subsequent tests of the deflection measurement system at Newport, RI., between Nov. 1-7, we discovered that significant system degradation had occurred.

During a data run, as described previously^[1], time-of-flight data is continuously streaming into the buffers inside the main computer (HP 380). This continuous streaming mode of operation is the only way of obtaining the necessary high speed data acquisition rate. After the data run is complete, a bit check is performed on each buffer. If the correct bit count is not obtained, the program exits and all information collected is lost. This is done because, if the bit counts are not correct, there is no way of determining later where in the data run the missing bits have been lost; and, if some data has been lost then all subsequent data is no longer in its correct position in the data matrices.

This type of controlled program crashing had only occurred infrequently before, independent of which scan pattern was used, even during the high sea states of the shakedown cruise. But the program was now constantly halting in this manner.

We modified the scan patterns used for the data acquisition program until we found groups of hydrophones that would run without aborting. By examining which hydrophones and star modules were producing these unexpected data dropouts we hoped to isolate the problem. Indeed, several of the star modules were no longer producing any output at all or were functioning sporadically. The computer controlled amplification on each nonfunctioning hydrophone was adjusted to maximum saturation levels in order to see if proper trigger levels could be obtained. For some of the hydrophones this adjustment of the amplification proved effective, but for most it did not. Also, we observed an additional problem of drifting DC power levels on the signal lines of the computer controlled amplification system.

We spent the week of Nov. 7-12 going over the problems cited above and attempted to arrive at possible solutions, assuming that the problems were caused by the equipment that we could access. If the problems were due to any of the system components inside the SRD area nothing could be done at this time. One of us (D. Weaver) flew to Newport and attempted to troubleshoot the system from Nov. 14-15. Initially, the system was working normally but over a 4-5 hour period of operation it began to degrade. However, the source of the malfunctions could not be located. The system was still functioning on a subset of the hydrophones, approximately 16-32, and occasionally some data could be obtained on some of the rest. This was deemed minimally sufficient to proceed with the sea test, especially to allow for environmental data collection in conjunction with deflection data.

Data Collection at Sea Trial

The sea trial experiment began on Nov. 15 at 5:00 p.m. and was conducted by J. Covey and L. Levenberry. Several pierside data runs were performed aboard the USS Kauffman in Newport, RI. before getting underway the next morning.

The ten day sea trial went from Newport, RI. to St. Johns, Antigua during Nov. 16-25. During the voyage we encountered sea states varying from smooth sea state 1 to very rough sea state 4. Altogether, we collected 27 data runs on 65 different hydrophones over ship speeds of from 3 to 21 knots. The Commanding Officer of the Kauffman deferred our dedicated test runs to the last two days of the voyage. However, by that time, the equipment inside the SRD had essentially ceased to function. Thus, most of the data runs taken earlier in the voyage were obtained on a not-to-interfere basis as the ship performed normal operations at relatively low speeds.

The data runs that were obtained used only 8 to 24 hydrophones each, making determination of overall SRD modal patterns difficult. A brief synopsis of the data collection schedule is listed in Table 1 below.

Table 1. Shipboard Activity Log

Date (1992)	Sea State	Location / Log Entry
Nov. 16	1-2	On the way to & after Norfolk, off the coast of Virginia. & NC. setting up new scan patterns and doing diagnostics
Nov. 17		setting-up new scan patterns and doing diagnostics
Nov. 18-20	3-4	Ship's sonar was active most of the time. But, we did manage to obtain several data runs during lulls in the ship's sonar activity.
Nov. 20		Our computer equipment area was closed for 24 hours due to a required ventilation period mandated by a fuel leakage in an adjacent compartment.
Nov. 21-23	3-4	obtained several data runs
Nov. 24	3-4	Ship's sonar went active prior to and during a 12 hour fleet missile launch exercise. Our system was mostly down, but a few data runs were obtained.
Nov. 25	3-4	Shutdown preparing to leave

Table 2 is a list of the data runs obtained during the voyage. For each data run we list the file name (for future reference); the name of the transducer scan pattern used for that run; the approximate sea state; the date and time; the size of the subsequent collected data arrays in disk sector blocks (this is useful mainly for data length comparisons and is a direct function of the time duration of the run); the ship's maximum speed during the run; the maximum ship roll in degrees; the measured sound speed of the water inside the SRD area (this was measured once just before each data run); the number of the asynchronous environmental data points collected; the total ship course change that occurred during the run; and the time delay used.

Table 3 lists the different scan patterns used during the sea trial, showing the hydrophones used for each one. The names of the scan patterns are in the first column with the set of hydrophones used in each scan pattern listed sequentially by scan position.

Table 2: Antigua Sea Trial Data Summary

File Name	Transducer Scan Pattern	Approx. Sea State	Date	Time	Size	Ship Speed (knots)	Max. Roll (deg)	c (m/s)	Env. data	Course Change (deg)	Delay (ms)
ANT_16D1	ANT16	1	15-Nov-92	22:01	617	0.0	1	1450.00	14	0	300
ANT16_D2	ANT16	1	15-Nov-92	22:17	6164	0.0	1	1450.00	140	0	300
ANT16_2_D1	ANT16_2	1	16-Nov-92	10:45	6172	20.0	2	1457.17	155	1	300
A16_3D1	ANT16_3	1	17-Nov-92	13:32	209	14.0	1	1466.49	10	1	300
ANT_16_3D2	ANT16_3	1	18-Nov-92	1:24	414	8.0	3	1471.78	15	0	300
SM00_16D1	SM00	1	18-Nov-92	1:32	414	8.0	2	1471.50	15	0	300
SM01_16D1	SM01	1	18-Nov-92	1:35	414	8.0	3	1471.48	15	1	300
SM02_16D1	SM02	1	18-Nov-92	1:46	414	8.0	3	1471.41	15	0	300
SM120_7D1	SM120_7	1	18-Nov-92	1:53	414	6.5	1	1471.19	15	4	300
LAST16_D1	LAST16	1	18-Nov-92	1:56	414	6.5	1	1471.19	15	1	300
SM00_16D2	SM00	1	18-Nov-92	8:16	414	3.3	1	1470.96	15	0	300
ANT_16_3D3	ANT16_3	2	18-Nov-92	9:18	4113	18.3	4	1470.74	100	4	300
ANT16_3D5	ANT16_3	1	18-Nov-92	13:03	3301	18.0	2	1469.23	100	0	300
ANT16_2D2	ANT16_2	1	18-Nov-92	16:29	3402	14-20.0	2	1468.86	100	3	300
ANT16D1	ANT16	1	18-Nov-92	16:45	3402	13.6	1	1468.69	100	1	300
BANT16_4D1	ANT16_4	2	19-Nov-92	22:11	3402	6.3	4	1491.65	100	1	300
BASM02_16D1	SM02	1	20-Nov-92	8:41	2488	2.4	3	1493.70	100	1	300
BANT16_4D2	ANT16_4	3	20-Nov-92	12:19	2488	5.0	9	1491.87	100	4	300
BANT16_4D3	ANT16_4	3	20-Nov-92	12:24	2488	5.0	11	1491.87	100	5	300
BA0001_16D1	A0001_16	2	20-Nov-92	12:50	2488	3.0	5	1491.82	100	2	300
BA0001_16D2	A0001_16	3	20-Nov-92	15:52	2488	5.6	12	1491.74	100	5	300
BA16_2D3	ANT16_2	3	20-Nov-92	18:26	2488	4.2	10	1492.63	100	7	250
CA2_27D1	CA2_27	3	20-Nov-92	22:42	3372	2.8	9	1494.19	100	74	250
CFA2_27D1	FA2_27	4	21-Nov-92	8:45	15919	4.4	14	1498.08	500	6	250
CFA3_27D7	FA3_27	4	21-Nov-92	22:40	15919	5.5	16	1499.34	500	10	250
CFA2_27D8	FA2_27	3	21-Nov-92	23:16	15919	4.0	9	1499.77	500	8	250
DF3_27D9	FA3_27	4	22-Nov-92	20:40	15919	6.4	15	1503.67	500	7	250
EANT_4_16D1	ANT16_4	3	23-Nov-92	6:33	16094	6.0	12	1504.94	500	7	250
FFA3_27D10	FA3_27	3	23-Nov-92	15:54	15919	2.0	7	1506.18	500	21	250

Table 3: Translucor Scan Pattern Index

Scan Pattern	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
ANT16	50	92	15	71	29	66	65	75	51	79	83	86	70	99	85	108											
ANT16_2	50	92	15	71	29	66	65	75	76	51	79	83	86	70	85	108											
ANT16_3	50	92	15	71	29	66	65	75	4	51	70	85	108	50	92	15											
SM00	60	21	44	41	59	40	24	31	23	58	45	22	7	42	68	43											
SM01	9	105	116	114	61	82	106	74	118	78	69	101	32	115	46	98											
SM02	50	72	87	67	92	15	128	71	29	66	65	80	75	76	4	51											
SM120	117	57	16	39	17	18	53	55	117	57	16	39	17	18	53	55											
LAST16	50	92	15	71	29	66	65	75	51	79	83	86	70	99	85	108											
ANT16_4	50	92	71	29	66	75	92	66	79	83	70	79	79	79	79	79											
A0001_16	21	59	40	31	42	68	82	106	74	118	78	69	115	46	98	50											
CA2_27	50	72	87	67	92	15	67	71	29	66	65	75	67	51	95	79	127	83	86	70	67	85	108	67	67	67	67
FA2_27	50	72	87	67	92	15	71	29	66	50	75	51	95	79	50	83	86	70	85	108	21	50	58	42	43	82	106
FA3_27	50	72	87	67	92	15	71	29	66	50	75	51	67	79	50	67	86	70	85	108	67	50	67	67	67	67	67

Note: The numeric values in the table refer to the SRD sensor location number as established by B.F. Goodrich and modified by NRL.

DATA GROOMING, CONVERSION, AND DISPLAY

We performed some data processing and statistical analysis shipboard, but this processing was largely designed for checking the performance of the system and insuring that the data being collected was not spurious. The main data grooming and conversion processes were done at NRL after the sea trial.

Description of Data Grooming process

The initial data grooming process consists of two stages. First, the data file is split into two, with the deflection data in one part and all of the environmental data in another. Then the deflection data is examined for outliers, and the different types of trigger threshold errors.

Outliers are caused by extraneous acoustic signals occurring during the data run and lead to false triggering of the timers. These are immediately obvious as they are usually far outside the normal time-of-flight values and are easily corrected by replacing them with an average value supplied by the two adjacent normal values. Very rarely, an outlier may involve more than a single point. But since the data runs are usually very long, involving thousands of time-of-flight readings, even these outliers can be replaced adequately by nearest neighbor averages.

Errors in trigger thresholds can occur for several reasons and require different solutions depending on cause, with the distinctions between the different types of errors not always being obvious. We first attempted to perform all of the data grooming by computer using an expert system program written by the authors. However, the varieties of trigger threshold errors encountered proved beyond the computer's ability to successfully classify. Thus, for the data grooming we used a composite program with many of the subroutines of the expert system program but still requiring extensive human decisions on the proper method for particular cases. Because of this, the final data is subject, to some extent, to known psychological evaluation limitations. We did make considerable efforts to avoid personal bias: by using four different people to perform data grooming with many of the data runs being rechecked by different people; and by basing most decisions about trigger errors on the performance of the hydrophone - receiver pair during pierside calibration runs.

Three different types of trigger threshold errors occurred. These three cases were distinguished by the amount of discontinuous time shifts that occurred in the data. Case 1 involved shifts of less than or equal to the period of the frequency used, i.e. $\Delta t \sim 10 \mu\text{sec}$. Case 2 involved shifts of between $10 \mu\text{sec}$ and $100 \mu\text{sec}$, and case 3 were a few rare cases (not counting the individual point anomalies classified as outliers) of time shifts greater than $100 \mu\text{sec}$.

Case 1 was due to triggering from one of the previous or subsequent peaks of the acoustic waveform signal instead of the main peak as intended. The acoustic waveform consisted of a single wave packet with cosine modulation of 4 to 5 peaks. These peaks were separated in time by the period of the frequency used, i.e. $\Delta t \sim 10 \mu\text{sec}$. By checking with the pierside calibration data the proper time shift of + or - Δt could be determined.

Case 2 was most probably caused by an acoustic multi-path problem. This would produce discrete jumps in the data as the signal would trigger off either the direct line-of sight signal or a multi-path signal over time periods governed by dome motions. This effect was due to the intensity changes in the received acoustic signals produced by the shifting of the main radiation lobe of the transducers by the dome motions. Again, by comparison to the zero deflection data the appropriate line segment of the correct data could be determined and the other shifted line segments could be vertically adjusted into alignment. After rescaling, the data was checked for correlation with the other receivers.

In the third case, an error was occasionally seen that was most probably due to switching noise or reverberation as these large shifts could not be explained by multiple path problems.

In some cases, in all of the above trigger errors, all efforts to rescale the data failed to produce data which correlated to the other receivers. When this occurred the data from that particular receiver was zeroed out and not used in subsequent calculations. This was possible since we had four receivers in each receiver array and only three were required for conversion to 3D coordinates. If more than one of the receivers failed in this manner then that hydrophone was dropped from the data completely for that particular data run.

Once these problems are corrected for each data run, the data is ready for conversion into 3D coordinates.

Co-ordinate Conversion and Display

The coordinate conversion process not only involved the calculation of x,y, and z coordinate values from the time-of-flight values and the measured sound speed, but also the transformation of reference frames from each of the separate frames of reference of the 10 different receiver arrays to the preselected global frame defined by BFG. This global frame had its origin at the top bow of the SRD. This program is described in Reference 1. This coordinate conversion process resulted in real time global 3D deflection measurement data. This data was also converted into displacement components normal to and inplane with the SRD surface at each point to aid in determining the types of motions occurring.

A real time 3D display of the data was used to examine SRD motions for typical modal response patterns. One time frame from a display of data taken during the shakedown cruise off the coast of Maine is shown in Figure 8. This shows three views of the entire data set: top, side, and front; as well as the displacement locus and the x component of displacement curve for the particular highlighted transducer. Similar displays for the data taken during the Antigua sea trial are less useful due to the smaller set of transducers in each data run.

DISCUSSION

The impact of the system degradation on fully achieving the goals of this test cannot be assessed at this time, but must await the results of subsequent data analysis and final comparison with the finite element predictions. Possible causes for system malfunction include water intrusion, shipboard environment, and electromagnetic interference.

Possible Water Intrusion

Water may have intruded into the cable connections, star modules, and/or the junction boxes submerged inside the SRD area.

The cable connections are a concern only due to the environmental conditions present during their installation. The particular type of connectors used are designed specifically for prolonged underwater use, and various offshore petrochemical facilities have found them to perform well. However they rely on rubber o-ring type seals to prevent water intrusion. During our installation, sandblasting was being performed overhead, and considerable grit was blanketing our work area. The shipyard was unable or unwilling to suspend these operations for our benefit. We believed at the time that we had taken reasonable precautions to keep these o-rings free of grit, since we recognized that any grit between the o-ring and its seal would allow water penetration. However in hindsight, we are now concerned that a very fine layer of dust may have contaminated these seals.

A second possibility is water leakage into the various underwater electronic modules. These units were manufactured as being only watertight and splash proof with a built in o-ring assembly. However, a layer of RTV was added during the sealing process and another RTV layer was applied to the exterior of the module around the o-ring area. Also, each module was pressure tested underwater to 100 psi during construction at NRL. But, it is possible that under extended pressure service over several months some water intrusion could have occurred.

Another possibility is equipment damage during dome installation. This would most likely take the form of cable crimping, pulling, or severing. It was unfortunate that the dome installation was not witnessed by personnel associated with this task area.

Shipboard Environment

Ship motion caused a number of broken wires and cables in accessible areas. These were located and repaired. The wave height sensor cable was also knocked loose during one test, resulting in a very incomplete data. A question remains, however, as to the integrity of all of the other cables in the inaccessible compartments.

Heat and air quality were also problems. Ventilation, as on most naval vessels, was poor and the work environment had temperature variations between 50 to 80 degrees Fahrenheit; also various fumes and vapors were prevalent from fuel, paint, and primer during the cruise. The ship log table shows several days were lost due to mandatory evacuation of the work area. These fuel, paint and primer vapors may have contributed to the degradation of the dielectric properties of insulators used in the specially built electronic subsystems.

Our power supplies also appeared erratic during the course of the test. In part this is due to fluctuations in the available shipboard power, and in one case a DC level shift on the waveform data lines was caused by a blown diode (which was subsequently replaced). However the causes of other fluctuations, such as the one resulting in erratic (computer controlled) amplifier performance, were unidentified.

Possible EMI Interference

Interfering radiated electrical signals may have originated from two sources: mutual inductance between nearby cables; and signals riding on our ground plane.

Concerning the former, it was previously mentioned that in consultation with Supship it was decided that the new separate cable way which we specified was not needed. This resulted in our cable runs sharing a cable way with all of the ship's sonar array cables including powerlines etc.

Concerning the later, while our equipment was designed for good ground-plane noise rejection, it is possible that some other instrumentation in use on the ship was dumping a larger than anticipated current to the ship's ground plane.

CONCLUSION

While the deflection measurement system suffered a performance degradation between the time of installation and the beginning of the Antigua sea trial, we still managed to obtain deflection data on 65 of the 128 hydrophones as well as extensive environmental data.

The impact of the system degradation on fully achieving the goals of this test cannot be assessed at this time, but must await the results of subsequent data analysis. At present, however, we believe that sufficient data was collected to fulfill the objective of the test: that is, to allow a direct calibration or validation of the Finite Element Model under development at APL, Seattle, WA.

ACKNOWLEDGMENTS

The authors would like to acknowledge the assistance of the officers and crew of the USS KAUFFMAN, and particularly the cooperation and continuous support provided by STGSC Terry. The authors would also like to acknowledge the assistance of several others at NRL who helped make this sea trial experiment possible. Cedric Beachem of Code 6320 helped to operate the deflection measurement computer system during the shakedown cruise off the coast of Maine. Howard Schrader and Kevin Groot, both from Geocenters Inc, provided assistance in several key areas including the installation of the hydrophones on the designated SRD at the B.F. Goodrich plant in Jacksonville, Fl and during the testing at CBD.

REFERENCES

[1] "Sonar Dome Reliability Assessment XVI: Acoustic Time-of-Flight Deflection Measurement System". NRL Memorandum Report 7354. By Joel F. Covey (Code 7135) and Diane B. Weaver (SFA Inc.). In preparation.

[2] "Sonar Dome Reliability Assessment XVII: Measured Deflections of the USS Yorktown Sonar Dome Rubber Window". NRL Memorandum Report 7355. By Joel F. Covey and Diane B. Weaver (SFA Inc.). In preparation.

AN/SQS-53 SDRW



AN/SQS-56 SRD



Figure 1: Sonar Dome Corrective Action Program

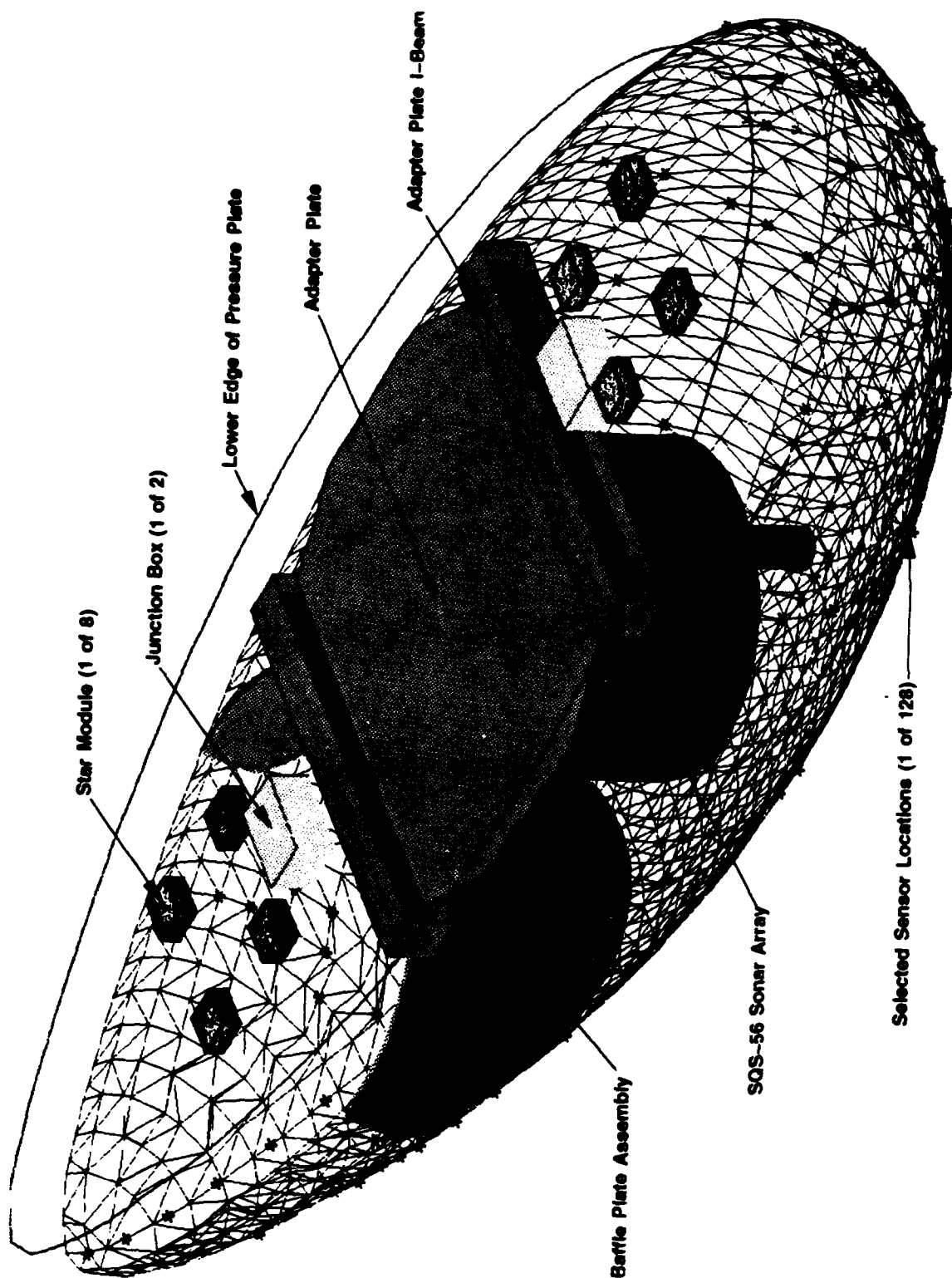
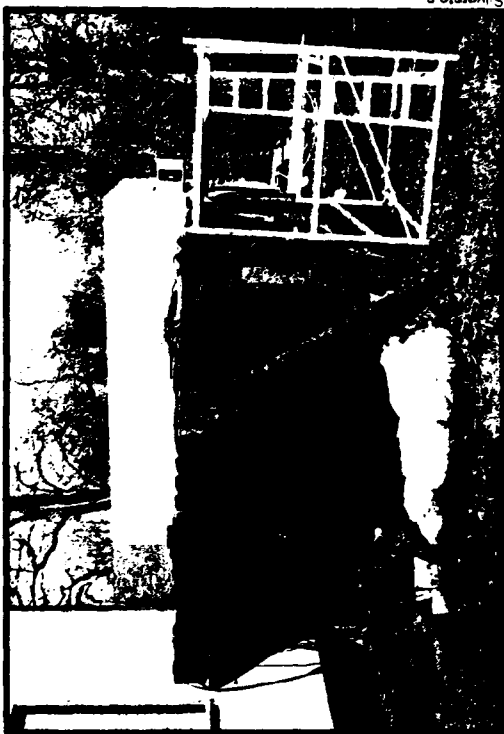
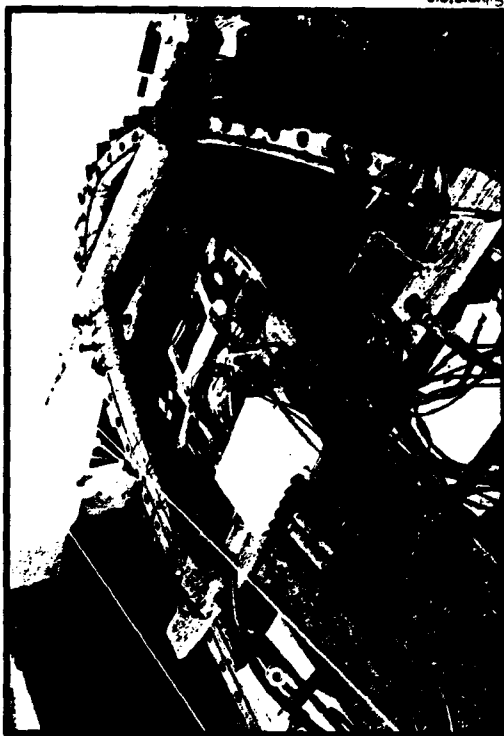


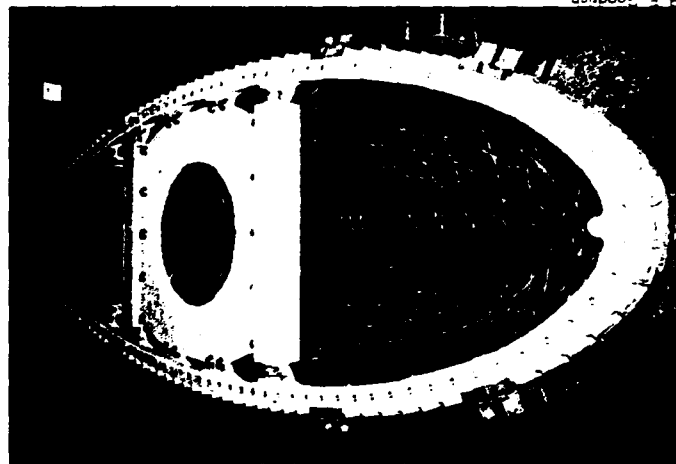
Figure 2: SDADMS Driver Transducer Locations



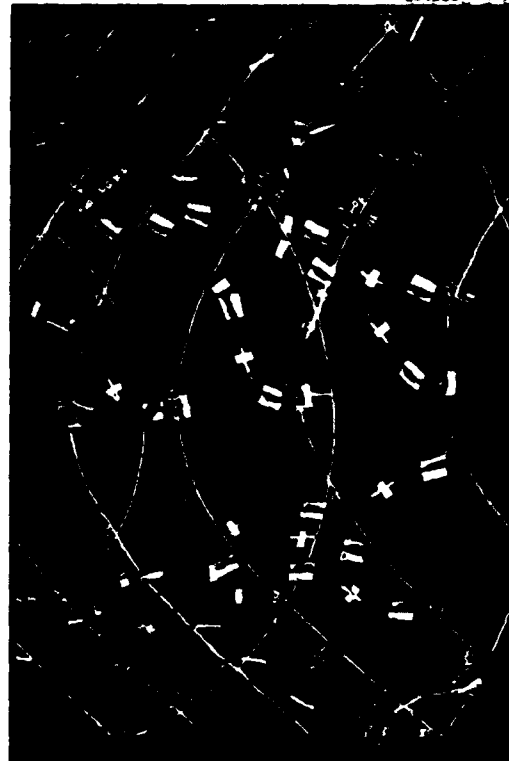
The set up at NRL/CBD



Junction Box, Star Modules and Floating Receiver Array



Completed installation at BFG



Coordinate grid and hydrophones in forward end

Figure 3: SDADMS Driver Transducer Locations

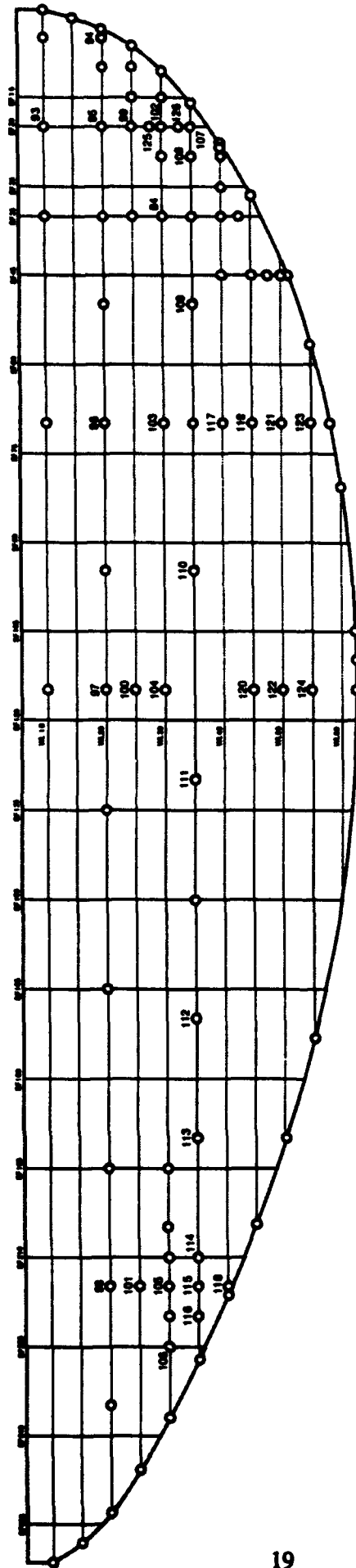


Figure 4: NRL Computer Model of SRD for Investigation of Deflection Sensor Locations

Port Side

Transducers 93-126

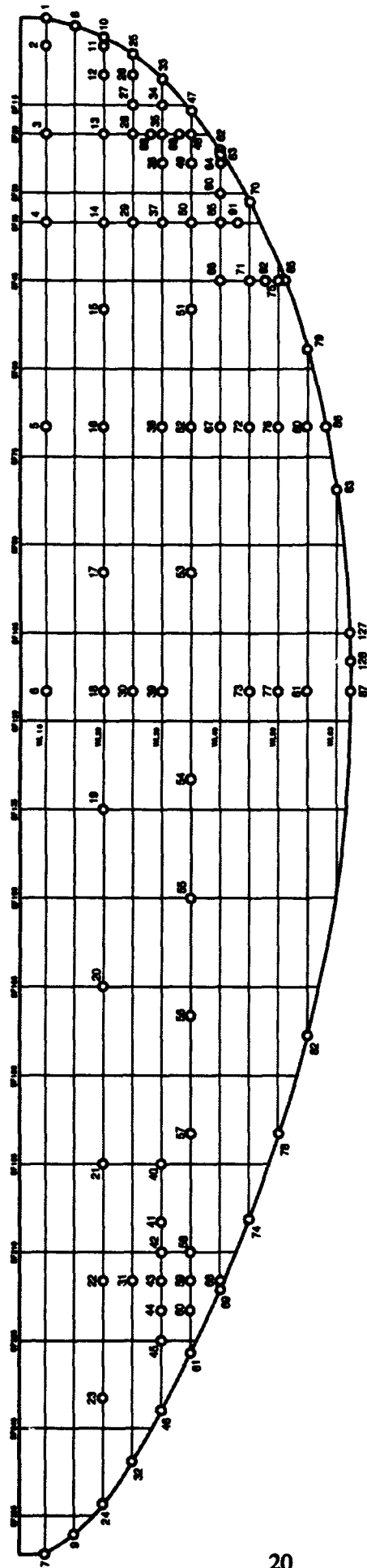


Figure 5: Preparations for deflection test of SRD

Starboard Side
Transducers 1-92, 127 and 128

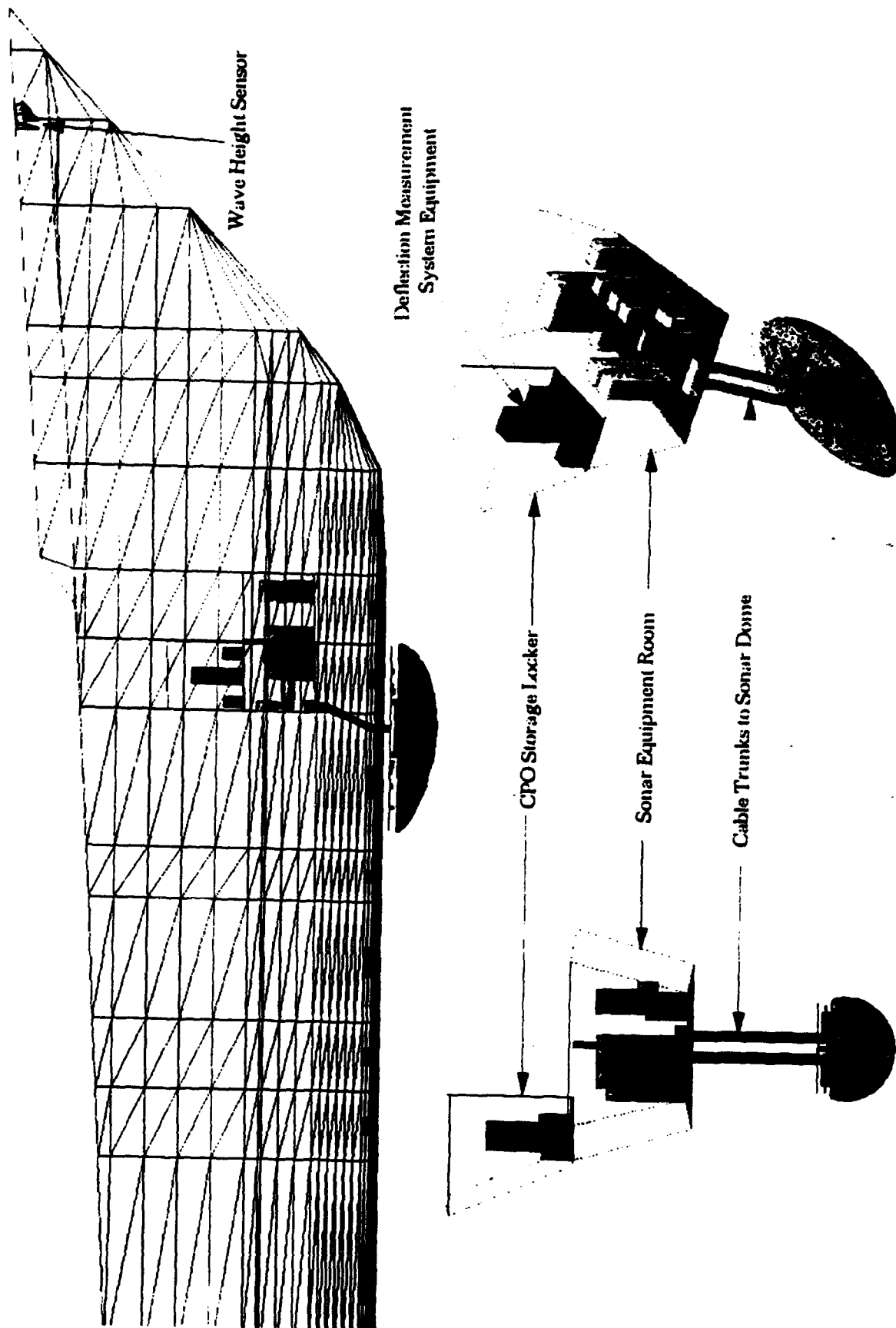
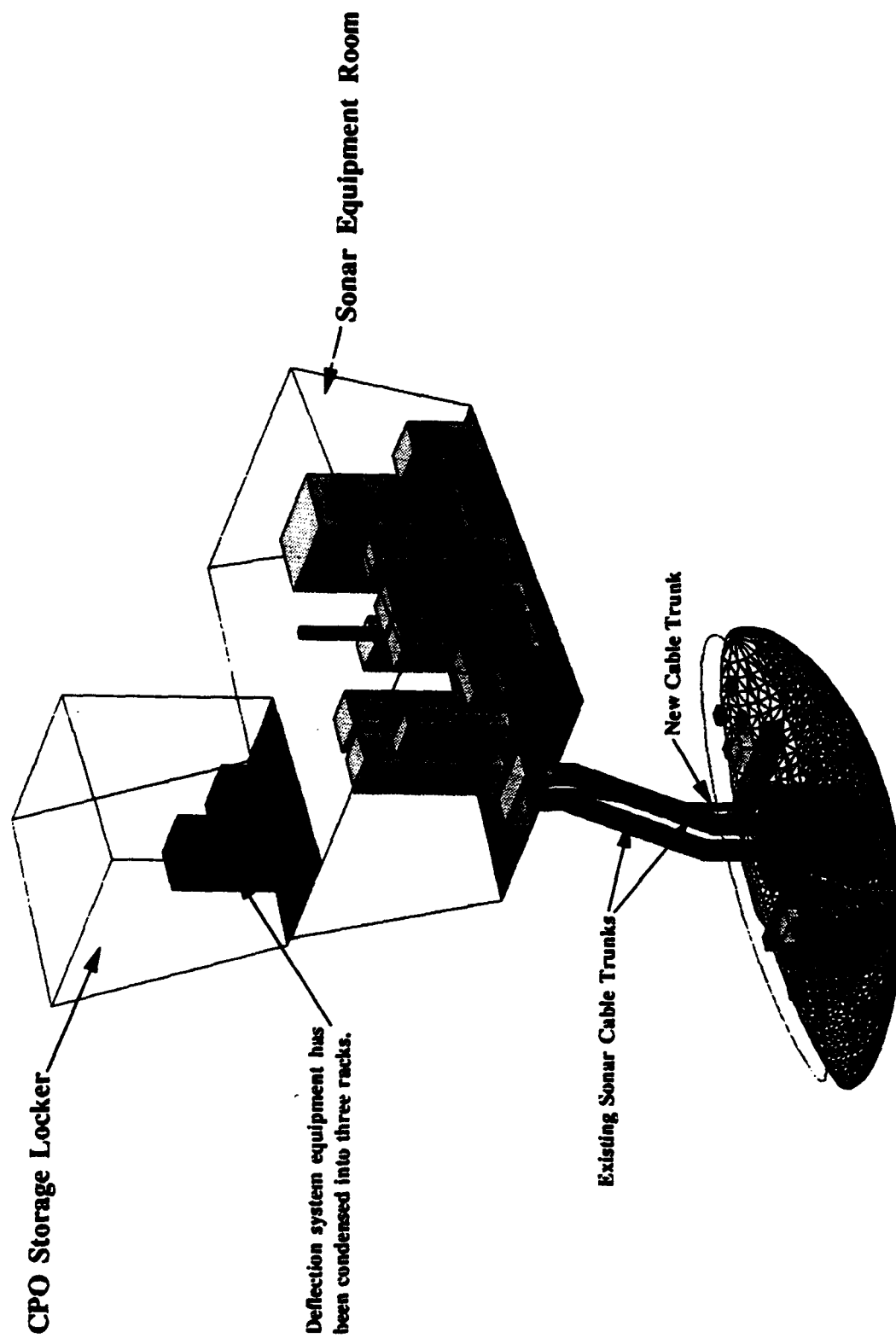


Figure 6: Placement of Deflection Measurement Equipment on USS Kauffman (FFG-59)



**Figure 7: SRD Deflection Measurement System
Equipment Arrangement**

Frame From Animated Data Display

Sea State 3

Deformations Exaggerated 75 Times
For Illustrative Purposes

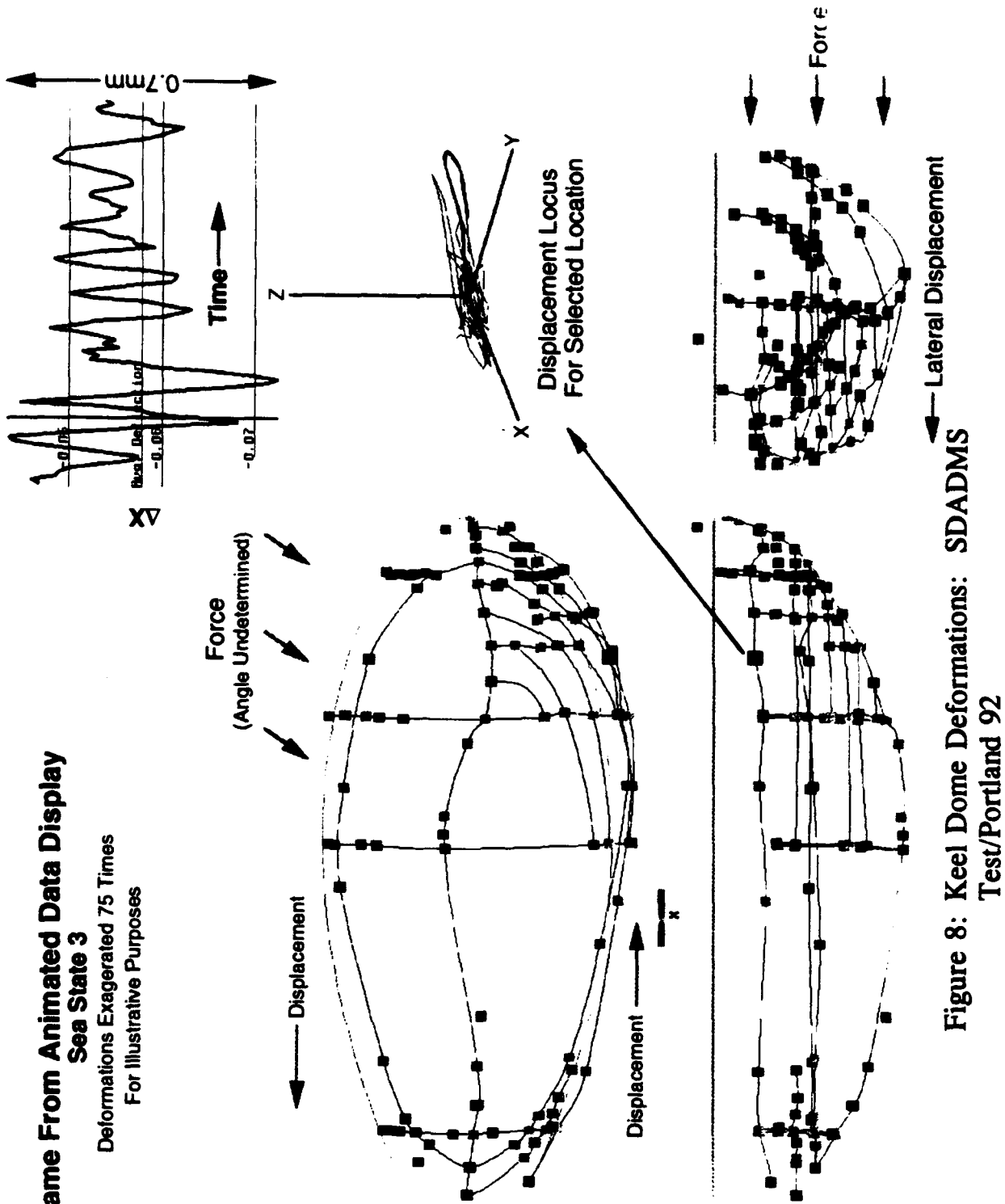


Figure 8: Keel Dome Deformations: SDADMS
Test/Portland 92

A PLAN FOR AT-SEA DATA COLLECTION USING THE SONAR RUBBER DOME DEFLECTION MEASUREMENT SYSTEM

1.0 INTRODUCTION

This document presents a plan for an at-sea full scale data collection run of the Naval Research Laboratory (NRL) Sonar Rubber Dome (SRD) deflection measurement system. This plan assumes that the participating Naval ship (an FFG-7 class) will be available for drydock modification, pierside testing, and at-sea data collection. Drydock installation will require approximately one week concurrent with other scheduled time (no extension of drydock time required). Subsequently, one week pierside will be necessary for calibration, and at least one week at-sea for data collection. Also, two days will be required after the at-sea data run for pierside equipment removal from the sonar equipment room. All installed items in the dome area will be removed during the next regular drydock cycle.

The at-sea tests can be performed on a not-to-interfere basis; but, if available, a series of one-hour periods of dedicated ship use would allow more precise deflection measurements to be obtained. During these periods of dedicated ship time measurements can be performed while maintaining specified ship speeds and constant course. Measurements can also be obtained during various ship maneuvers, such as high speed turns.

2.0 PURPOSE

The purpose of this sea trial is to obtain a 3D data base of sonar rubber dome deflections in real-time, correlated to ship motion, sea state, and internal pressure.

3.0 GENERAL TEST RATIONALE

NAVSEA has a continuing effort to increase SRD lifetimes and provide solutions to at-sea failure problems. This effort includes research currently underway in the areas of material property analysis, failure analysis, and radiographic and other non-destructive testing. To fully interpret the results of the above research, and to provide a foundation and calibration for computer generated models of SRD behavior, a direct experimental measurement of at-sea SRD deflections under operational conditions is essential.

Past at-sea tests of the sonar dome rubber window (SDRW) using a similar deflection measurement system, supplied this type of vital data required for the redesign and improvement of the SDRW. The current system would perform the same mission for the SRD.

4.0 TEST OBJECTIVES

The major objectives of the deflection measurement program are to:

- (a) provide data from an instrumented operational ship to guide future SRD design modifications.
- (b) accumulate a full scale data base for characterizing SRD deflections, correlated with internal pressure, ship motions, and sea state.

5.0 TEST SUMMARY

5.1 DRYDOCK INSTALLATION

The drydock phase will involve ship modification, installation of cables and electronic modules in the sonar dome area, installation of two large and two small equipment racks into the sonar equipment room, and a modified SRD mounting procedure.

The following ship modifications are required:

(a) an additional cable-way must be installed through the void area between the sonar equipment room and the sonar dome pressure plate, leading to the ships sonar array. This cable-way must be large enough to accommodate two 1.25 inch diameter electrical cables (type 2SWF-24). The military specification sheets for this 48 conductor (i.e. 24 shielded twisted pair) electrical cable is included in Appendix (1).

(b) Two new stuffing tubes must be installed on top of the sea chest located in the sonar equipment room. Each stuffing tube must be large enough to allow passage for one 1.25 inch diameter cable (as discussed in 5.1 (a) above).

(c) Twenty (20) pre-drilled rectangular steel support brackets (or bars), 4 type (a) and 16 type (b), must be welded to the bottom (outer side) of the sonar pressure plate at locations to be specified during drydock installation. These support brackets will be supplied by NRL. Appendix (2) contains a drawing of the SRD pressure plate showing the approximate location for the two junction boxes and eight star modules that will be installed. Two support bars need to be welded onto the pressure plate for each box or module. Appendix (3), parts (a) and (b), contain the drawings for the two types of support bars required; one for the junction boxes, type (a), and the other for the star modules, type (b). Before welding, the acoustic rubber applied to the bottom side of the sonar pressure plate must be removed from those areas immediately around the attachment sites. After all twenty brackets have been welded, the acoustic rubber must be remounted onto the pressure plate.

(d) Support brackets must be installed (welded) onto the bow for the wave height sensor. The attaching cable must be routed from the bow to the sonar equipment room through available stuffing tubes to allow for shipcheck watertight conditions. The support bracket will be supplied by NRL. Exact mounting locations on the bow will be determined during drydock installation.

(e) Two flanges must be welded to the pressure plate for the mounting of two conductivity sensors. Appendix (4) contains a drawing of the required flange which will be provided by NRL. As in (c) above, the acoustic rubber must be removed from the immediate site before welding, and replaced after the flanges have been attached. Exact locations for welding the flanges will be provided during drydock installation.

(f) A 90° elbow adapter, supplied by NRL, must be installed for the fill tube which drops down into the SRD from the pressure plate. This is to route the fill tube forward so that it drops down between the sonar array and the baffle plate.

The modified SRD mounting procedure will involve moving the SRD up to within 2 feet of the pressure plate and then pausing for 1-2 hours for final wiring of the deflection measurement system, before continuing with the normal attachment procedure.

5.2 PIERSIDE TESTS

The pierside phase will involve a one week period for equipment and system calibration with no change in normal ship activities.

5.3 AT-SEA TESTS

During the at-sea portion of the test the following measurements will be performed:

(a) SRD deflection measurements will be performed at those locations where hydrophones are attached. These measurements will be performed in a number of scans to obtain the maximum phase correlation to ship motion.

If dedicated ship time is available the above measurements will be performed at different ship speeds, i.e. at 5, 10, 15, 20, 25, and 30 knots. If possible, the ship will also be requested to conduct maneuvers at the previously mentioned speeds. The maneuvers would include maintaining a heading for 10 to 20 minutes, conducting figure eight turns at hard rudder angles, and zig-zags to allow for the monitoring of SRD deflection and vibration modal patterns. It is requested that the ship's sonar not go active from the time of initial installation until the above measurements have been taken, if ship operations permit. No special weather conditions or geographic areas are required to complete the at-sea portion of this test. It is, however, desirable to perform measurements over the widest possible range of sea states that may be available within the time and range limits imposed by the Ship's schedule.

(b) Measurements of relative ship motion will be obtained from monitoring Ship's attitude by direct connection to the Ship's course and speed Logs in the sonar equipment room, and from a triaxial accelerometer, two linear accelerometers, and two force balanced inclinometers. Internal pressure in the dome area will be monitored in two locations, as well as temperature, conductivity, and sound speed. The wave height sensor, mounted on the bow, will provide data useful in estimating sea state.

5.4 PIERSIDE EQUIPMENT REMOVAL

After the at-sea data collection, during the subsequent period of pierside docking, all test equipment located in the sonar equipment room will be

removed. This will take approximately two days.

6.0 TEST REQUIREMENTS

The following items are required for successful completion of the sonar rubber dome deflection measurement system:

- (1) A ship with an AN/SQS-56 sonar system, preferably an FFG-7 class ship.
- (2) 5 power outlets each with 110 to 120 VAC, 15 amps, available in the sonar equipment room.
- (3) Space requirements in the sonar equipment room include approximately 21 square feet of deck space.

Two to four members of the NRL/NAVSEA test team will be required to embark with the ship in order to conduct the tests and all test equipment will be provided by NAVSEA through NRL. The installation and removal of test equipment will be performed by NRL and NAVSSES personnel, with assistance from ship and drydock personnel.

The time requirements, as mentioned in the introduction, include: one week in drydock, one week pierside for calibration, and at least one week of at-sea time with sequences of one hour periods of dedicated ship use for data collection. Also, two days will be required pierside for equipment removal. If additional at-sea time is available, more data runs can be performed at the different ship speeds listed above for as many sea states as possible.

7.0 TEST EQUIPMENT

The following test equipment for the sonar dome deflection measurement system will be provided by NRL:

- (1) HP9000/350 (or 380) and HP9000/332 System Controllers
- (2) two HP9153C 20MB Hard Disc/3.5 inch Floppy Disc Drives, an HP9145 Tape Drive, and an HP C1701A 650 MB Magneto-Optical Removable Disk Drive.
- (3) four HP5345A High Speed Event Timers
- (4) HP3457A Digital Multimeter
- (5) HP8116A Programmable Function Generator
- (6) Racal-Dana 1515 Pulse Delay Generator
- (7) Two Tektronix TM5006 Plugin mainframes with DM5010 Digital multi-meter, FG5010 Programmable Function Generator, PS501 and PS503 power supplies, DC5009 Universal counter, FG501A Function Generator, and two AM502 amplifiers.
- (8) Tektronix 2235 Dual Channel Oscilloscope
- (9) two SI701B force balanced inclinometers, and an SA307 triaxial accelerometer
- (10) HP5183U Digital Oscilloscope Display unit

- (11) two HP5183A 2 Channel Waveform recorders
- (12) RMU2000 wave height sensor, including two acoustic transducers and two linear accelerometers
- (13) two HR203 Digital to Synchro converters
- (14) Omega Digital thermometer
- (15) two HP35731A Monochrome Monitors
- (16) two HP46021A computer keyboards
- (17) HP2228A QuietJet printer
- (18) NRL-DMux1 128 Channel Demultiplexer including two main junction boxes and ten star modules
- (19) two ENI 240L RF Power Amplifiers.
- (20) two Ithaco 4302 Dual Filters.
- (21) Global C4089 Electrical line conditioner.
- (22) Acoustic Hydrophones for the transmitter and receiver arrays.
- (23) Elastolock AS-1 or Biggs A&B Epoxy-Putty adhesive for mounting the acoustic hydrophones.
- (24) Battery powered drill and attachments for cleaning metal surfaces inside the SRD area.
- (25) Miscellaneous cables: One reel of RG/58 coax cable with associated BNC connectors; various fixed length BNC cables; Wire rope cables, clamps and other items for securing the above electronic equipment to the ship.
- (26) Assorted tools: scraper, sandpaper, screw drivers, chisel, hammer, special clothing, and cleaning cloths, etc.
- (27) Outlet Power strips

8.0 MANNING REQUIREMENTS

The following agencies will supply the necessary manpower to support the test program:

- (1) Naval Sea Systems Command (Code 06U1D)
- (2) Test Ship - Naval Surface Force, U.S. Atlantic Fleet
- (3) Naval Research Lab
- (4) Naval Ship Systems Engineering Station
- (5) Drydock (or Shipyard)

9.0 RESPONSIBILITIES

The following agencies will be responsible for the listed items or portions of the sonar rubber dome deflection measurement system:

9.1 NAVSEA CODE 06U1D

- (1) Has overall responsibility for the conduct of the data collection program.
- (2) Provide transportation of all equipment and personnel to the ship.

9.2 NAVAL RESEARCH LABORATORY

- (1) Provide equipment as listed above.
- (2) Supply, install, monitor, and remove deflection system.
- (3) Provide 2-3 personnel required to install, calibrate, and operate the data collection instrumentation.

9.3 NAVSSES

Provide 1-2 personnel to NRL in supporting the installation in drydock, the equipment calibration pierside, and the at-sea measurements.

9.4 TEST SHIP

- (1) Provide 4-6 personnel to assist in equipment installation, securing equipment to the ship, and removal.
- (2) Provide communication between the sonar equipment room and ship control. Allowing access to information on ship speed, course, approximate sea state, sea water temperature, and local meteorological data.
- (3) Maintain accurate logs of the dome pressurization system including any alarms noted. Change internal pressurization levels of the dome areas at request of test personnel (optional).
- (4) If ship schedule permits: set and maintain ship course and speed as requested during one-hour dedicated ship use periods.
- (5) Maintain ship sonar silence from the time of pierside installation until after initial test measurements at sea.

9.5 DRYDOCK (or SHIPYARD)

- (1) Install support brackets described in Appendix (3) (4 type (a) and 16 type (b)) and weld to pressure plate.
- (2) Perform the installation of the new cable-way.
- (3) Install new stuffing tubes.
- (4) Install support structure for wave height sensor on bow, and route associated cable to sonar equipment room through stuffing tubes to allow for watertight conditions.
- (5) Assist in the modified installation procedure for the SRD.

MIL-C-915/48B
18 June 1985
SUPERSEDING
MIL-C-915/48A
1 August 1972

MILITARY SPECIFICATION SHEET

CABLE, ELECTRICAL, TYPE 2SWF

This specification sheet is approved for use by all Departments and Agencies of the Department of Defense.

The complete requirements for acquiring the cable described herein shall consist of this document and the latest issue of MIL-C-915.

REQUIREMENTS:

Qualification required.

Construction (watertight)

- First - Copper, conductor, in accordance with ASTM B 286, size 22-7, tin coated. Maximum diameter 0.033 inch.
- Second - Polyethylene insulation, natural, type II, class L, grade 4 in accordance with L-P-390. Nominal thickness 0.010 inch. Colored insulation, one black and one white conductor for each pair.
- Third - Clear polyamide jacket on each conductor in accordance with ASTM D 4066. Nominal thickness 0.003 inch.
- Fourth - Two conductors, one black and one white, cabled together with nominal lay of 2.5 inches to form each pair.
- Fifth - Binder tape over each pair, at manufacturer's option, applied helically with overlap.
- Sixth - Braided shield of AWG no. 34 or no. 36 tin coated copper. Braid angle 30 to 35 degrees; minimum coverage of 85 percent.
- Seventh - Shield insulation of one polyester tape, type J in accordance with MIL-I-631 plus a jacket of clear polyamide in accordance with ASTM D 4066. Nominal thickness of 0.003 inch. Standard identification code applied by method 2.
 - Alternate shield insulation of two polyester tapes, type G of MIL-I-631, sealed. Standard identification code applied by method 2, on inner tape.
- Eighth - The required number of pairs (see table I) cabled with a lay not greater than 24 times the pitch diameter of the layer. Cabling sequence shall be consecutive, starting with pair no. 1, from center outward. Nonfibrous fillers shall be employed.

FSC 6145

DISTRIBUTION STATEMENT A Approved for public release; distribution unlimited

Appendix (1) of Enclosure (1)

MIL-C-915/48B

- Ninth - Synthetic rubber compound filled binder tape applied helically with overlap. (Surface of tape shall be such that cable jacket will adhere to it.)
- Tenth - Arctic tape polychloroprene jacket (black). (See table I for thickness.) Cable surface marking required.

TABLE I. Details.

Type and size	Number of pairs	Cable jacket thickness minimum (inch)	Overall diameter	
			Minimum (inch)	Maximum (inch)
2SWF-3	3	0.100	0.600	0.625
2SWF-4	4	.090	.600	.625
2SWF-7	7	.110	.780	.815
2SWF-24	24	.125	1.190	1.250

12.26/ft

EXAMINATION AND TESTS:

Requirements

Basic electrical:

Conductor resistance - ohms/1000 feet, at 25°C, maximum.	17.71
Voltage withstand - volts, root mean square, minimum	
Conductor to conductor.....	2000
Conductor to shield.....	1000
Shield to shield.....	500
Insulation resistance - megohms/1000 feet, minimum	
Conductor to conductor.....	3000
Conductor to shield.....	1500
Shield to shield.....	100

Group A:

Visual and dimensional.....	No failure
Hydrostatic (open end) - leakage 1000 lbf/in ² , in 6 hours, in ³ , (test each snipping length).....	Zero
Capacitance	
Mutual capacitance - at 1 MHz, pF/ft, maximum.....	30
Capacitance unbalance - percent, maximum.....	8
Characteristic impedance - at 1 MHz, ohms.....	75 ± 5

Group B:

Attenuation - at 3 MHz, db/100 feet, maximum.....	3
Cold working (minus 54 ± 2°C).....	No damage
Drip - at 75 ± 1°C.....	Zero
Physicals (unaged)	
Insulation (conductor)	
Tensile strength - lbf/in ² , minimum.....	1400
Elongation - percent, minimum.....	300
Jacket (cable)	
Tensile strength - lbf/in ² , minimum.....	1800
Elongation - percent, minimum.....	300
Set - inch, maximum.....	3/8

EXAMINATION AND TESTS: (Continued)

RequirementsGroup C:

Physicals (aged)

Insulation (conductor)

Air oven

Elongation - percent of unaged, minimum..	60
Permanence of printing (jacket) - cycles, minimum.....	250
Cable filler removability.....	No failure
Shield-conformance to material coverage and construction	No failure

QUALIFICATION INSPECTION:

Qualification inspection shall include basic electrical, all of groups A, B and C, plus the following:

Cable aging and compatibility ($95 \pm 3^{\circ}\text{C}$).....	No failure
Cold working (minus $54 \pm 2^{\circ}\text{C}$).....	No failure

UNIT ORDERING LENGTHS:

All sizes 1000 feet (nominal).

Revision letters are not used to denote changes due to the extensiveness of the changes.

NOTE: Not for Air Force use.

Custodians:

Army - MI

Navy - SH

Preparing activity:

Navy - SH

(Project 6145-0685-43)

Review activities:

Army - CR, ER

Navy - EC

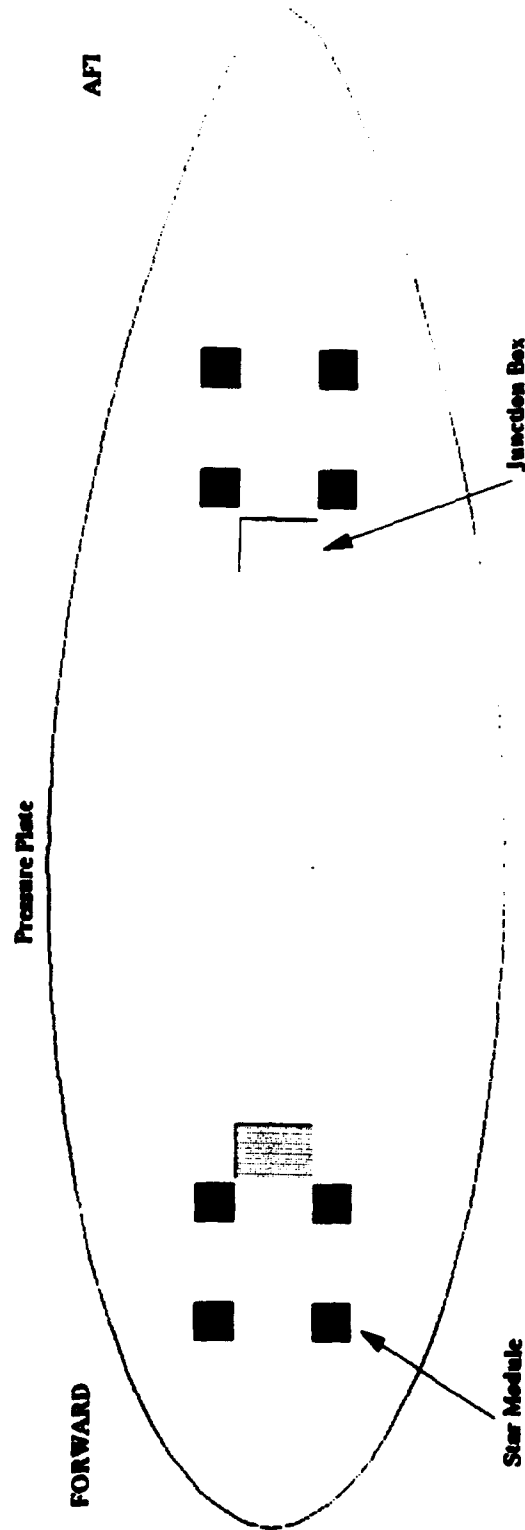
DLA - IS

User activities:

Army - AL, AR, ME

Navy - CG

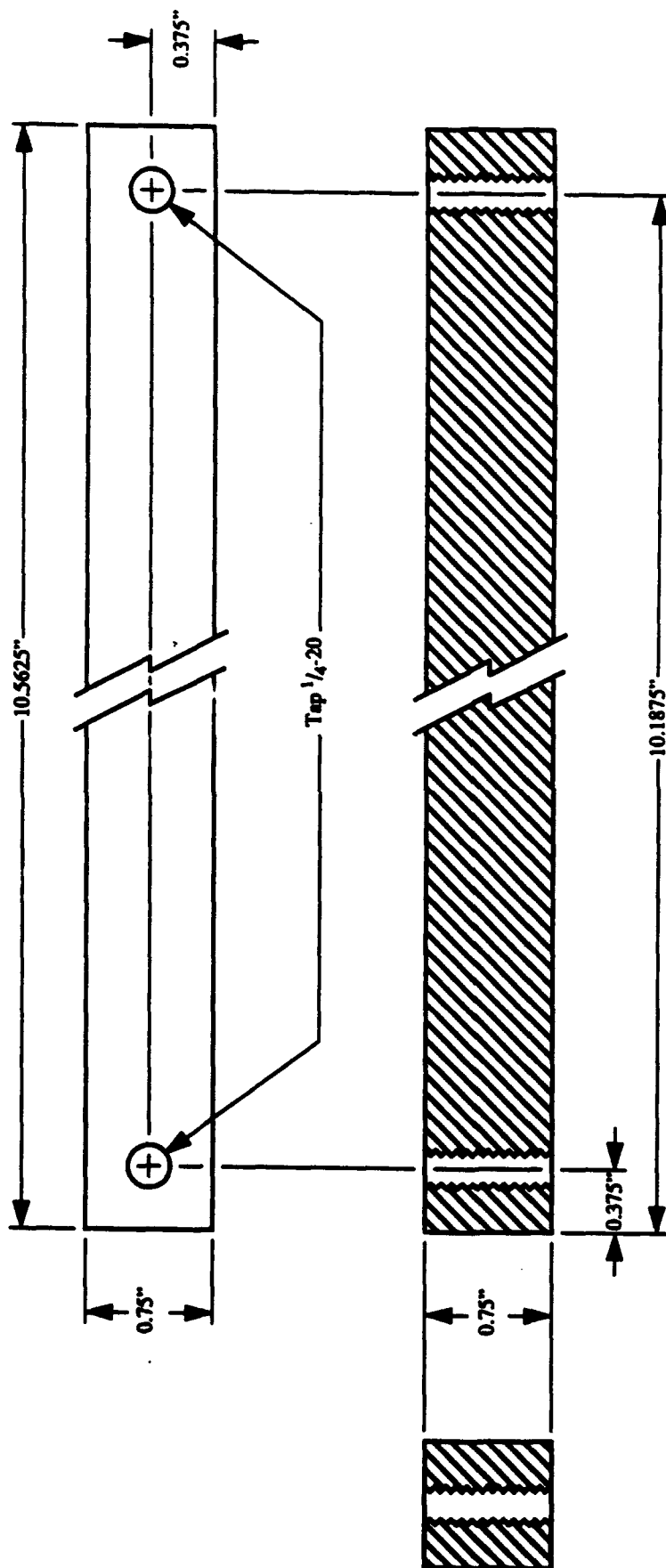
Appendix (2): Pressure Plate Weld Locations



WELD LOCATIONS: Two support brackets (or bars) will be welded onto the pressure plate for each star module and junction box, for a total of 20 welds. One bar forward and one aft for each unit to be installed. Approximate locations are shown above. Exact weld locations will be provided by NRL personnel during drydock installation.

Enclosure (1)

Appendix (3a): Junction Box Mounting Bar

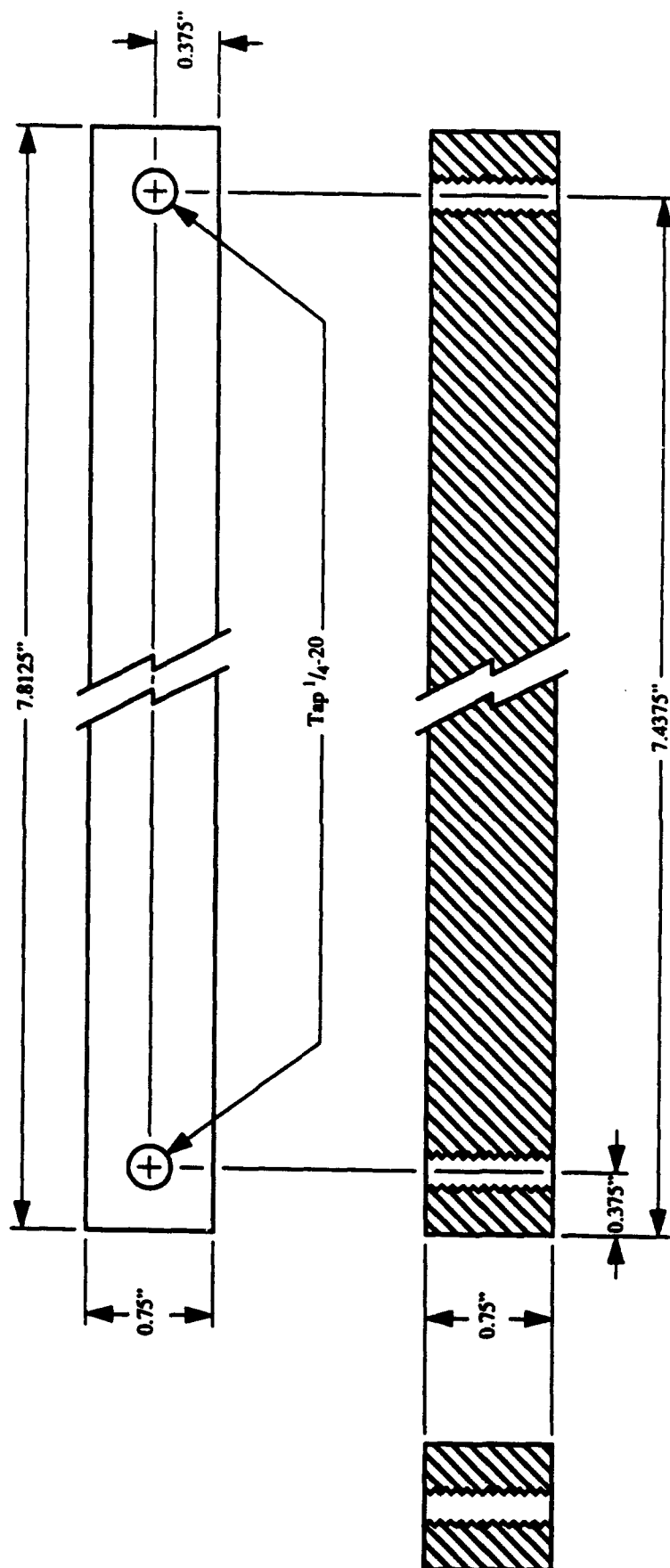


Notes: The material used is Carbon Steel Square Stock; 4 pieces were made.

The Shipyard must arc weld these to the SRD Pressure Plate at locations specified by an on-site NRL representative.

Enclosure (1)

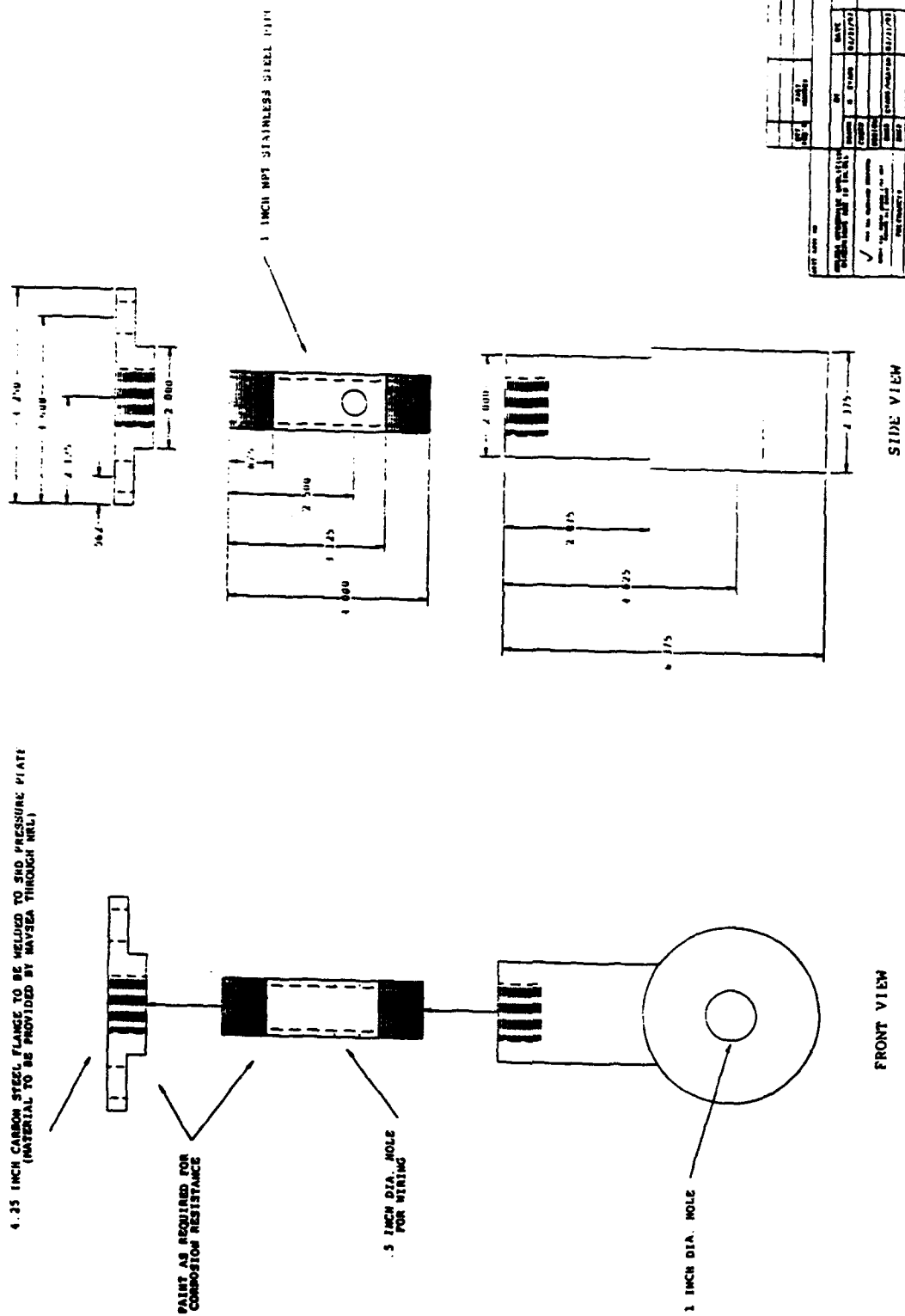
Appendix (3b): Star Module Mounting Bar



Notes: The material used is Carbon Steel Square Stock; 16 pieces were made.
The Shipyard must arc weld these to the SRD Pressure Plate at locations specified by an on-site NRL representative.

Enclosure (1)

Appendix (4) of Enclosure (1).

[illegible]

Enclosure 2:

Additional Ship Modifications for the Sonar Rubber Dome Deflection Measurement System At-Sea Data Collection Plan

The following items should be added to the indicated sections of the test plan dealing with drydock installation:

- 5.1. (b): [Add 2 tasks - installing cable and sealing stuffing tubes]
After the new cable-way and stuffing tubes have been installed as in 5.1 (a) and (b) the two 1.25 inch diameter cables supplied by NRL must be installed and the stuffing tubes sealed watertight. The cable installation should be routed from the sonar array through the cable-way to the sonar equipment room and then through existing stuffing tubes or overhead opening to the CPO storeroom compartment # 3-40-2-A.
- 5.1. (c): [clarification]
NRL personnel will mark out a grid system on the underside of the pressure plate. Using this grid system they will also specify the exact locations for welding the steel support brackets.
- 5.1.(d):[Add 3 tasks plus clarification - installing stuffing tubes on bow, installing cable, and sealing stuffing tubes]
Install 2 new stuffing tubes on the bow 17 ft. forward of the forward perpendicular and 3 ft. to port and starboard of centerline as shown in enclosure (1). These stuffing tubes are to be used to route the cables from the wave height sensors to the CPO storeroom compartment # 3-40-2-A (cable will be supplied by NRL). The new stuffing tubes must then be sealed watertight. The support brackets for the wave height sensors consist of 14 carbon steel plates provided by NRL (7 for each side, port and starboard). These plates must be welded together and these two fairings then welded to the Ship's hull. This welding process involves approximately 25 linear ft. of welding. The exact location for welding these fairings onto the Ship's hull will be provided by NRL personnel at the shipyard. NRL requests that this task be delayed as long as possible during the Ship's drydock period.
- 5.1.(f): [Add 4 tasks with clarification - cutting, threading, and installing NRL supplied tubing for the fill tube; and attaching pipe to pressure plate with pipe hangers]
The 90° elbow adapter supplied by NRL consists of the following parts: two 90° brass elbows and a 12 ft. brass pipe. The pipe must be cut to length to be specified by NRL personnel at the drydock and threaded on both ends to allow connection to the elbows. This new fill tube pipe (2 3/8 inch dia.) must then be attached to the pressure plate with pipe hangers for the supplied by the Shipyard.